THE PRINCIPLES OF PHILOSOPHY.

Fig.1.

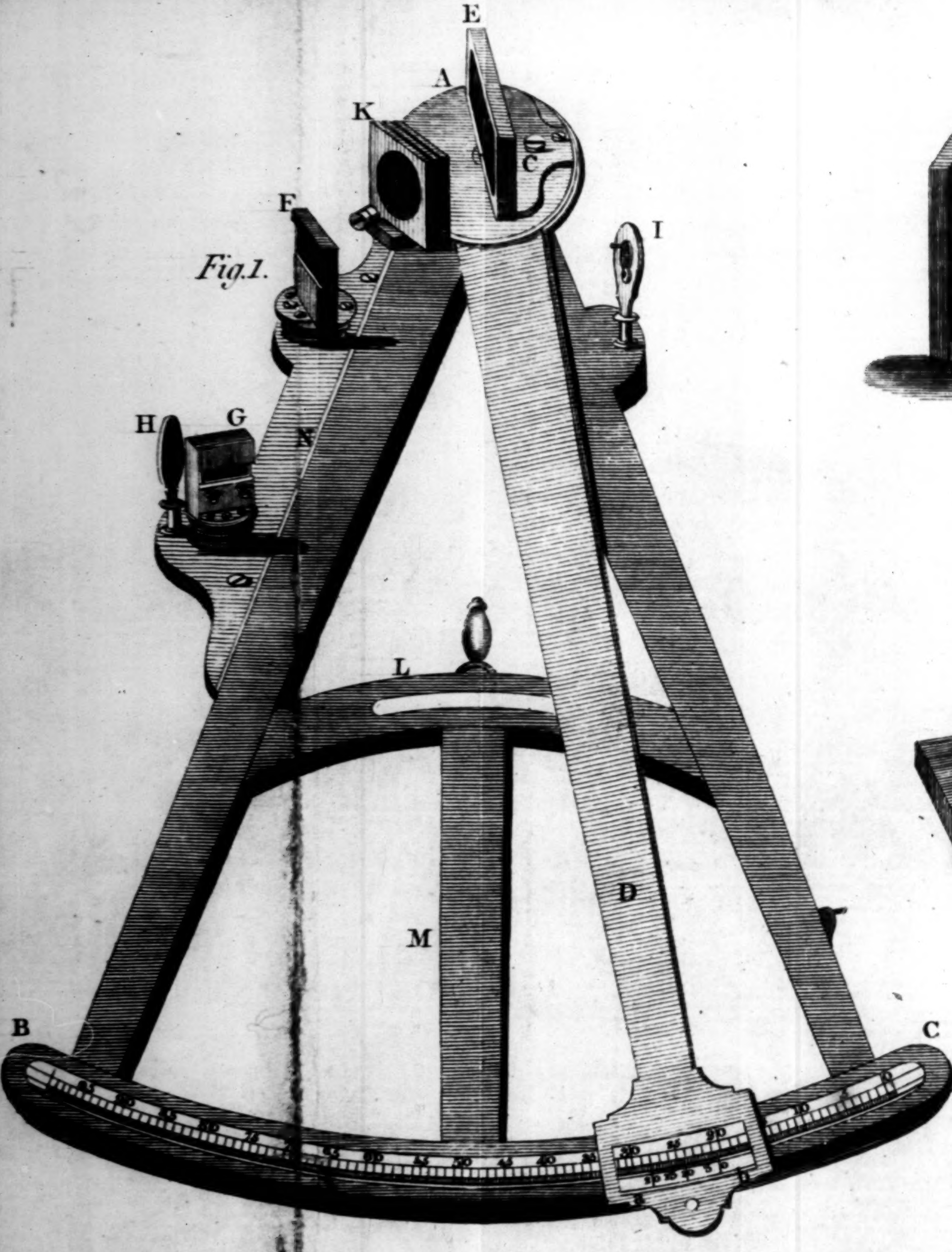


Fig.2.

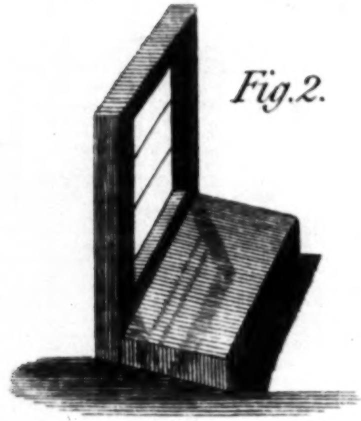
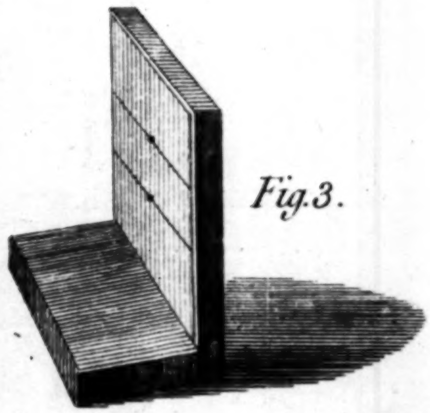
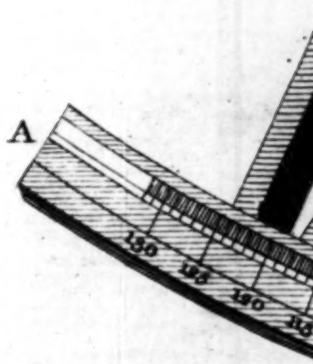


Fig.3.





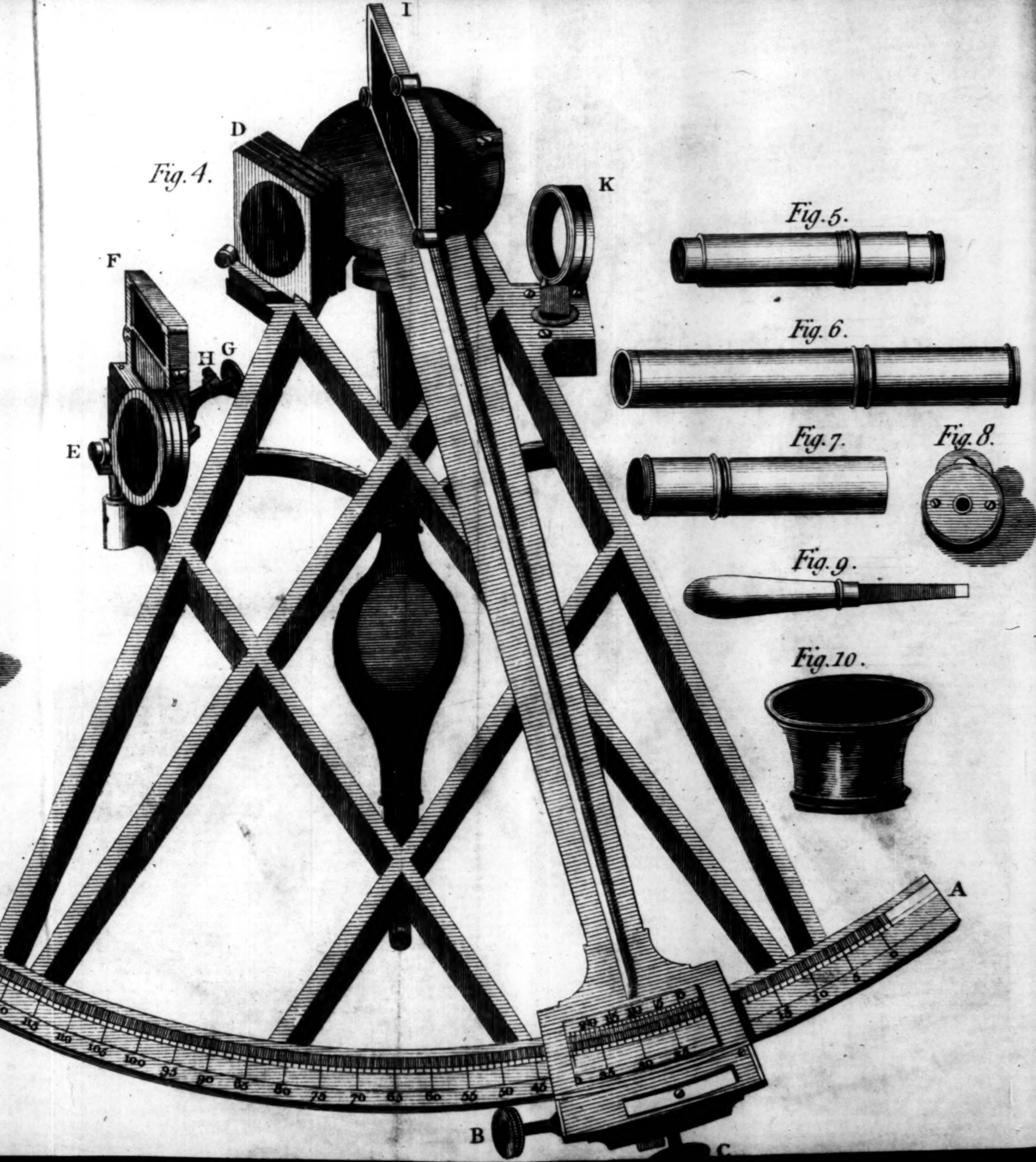


Fig. 4.

Fig. 5.

Fig. 6.

Fig. 7.

Fig. 8.

Fig. 9.

Fig. 10.

DESCRIPTION, USE, 3.

AND

METHOD OF ADJUSTING *HADLEY's* QUADRANT AND SEXTANT.

By GEORGE ADAMS,

MATHEMATICAL INSTRUMENT MAKER TO HIS MAJESTY, AND OPTICIAN TO HIS ROYAL HIGHNESS THE PRINCE OF WALES.

LONDON:

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DESCRIP-

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AND

METHOD OF ADJUSTING

HADLEY's QUADRANT,

AS MADE AND SOLD

By GEORGE ADAMS,

Mathematical Inſtrument Maker to His Majeſty, and Optician to His Royal Highneſs the Prince of Wales,

At TYCHO BRAHE's Head, No. 60, FLEET-STREET, LONDON.

"AT the appointed time, when it pleaſed the Supreme Diſpenſer of every good gift to reſtore light to a bewildered world, and more particularly to manifeſt his wiſdom in the ſimplicity, as well as in the grandeur, of his works, he opened the glorious ſcene with the revival of ſound aſtronomy." This obſervation of an excellent philoſopher and phyſician * is verified in every inſtance of the progreſs of ſcience; in each of which we may trace ſome of the ſteps of that vaſt plan of Divine Providence, to which all things are converging, namely, the bringing all

* Sir John Pringle's Six Diſcourſes to the Royal Society.

all his creatures to a ſtate of truth, goodneſs, and conſequent happineſs; an end worthy of the beſt and wiſeſt of beings, and which we may perceive to be gradually effecting, by the advancement of knowledge, the diffuſion of liberty, and the removal of error, that truth and virtue may at laſt ſhine forth in all the beauty of their native colours.

It is thus that the diſcovery of the compaſs gave riſe to the preſent art of navigation; and when this art grew of more importance to mankind, Divine Providence bleſſed them with the invention of Hadley's quadrant, and in our own day and our own time has further improved both it and the art of navigation, by the preſent method of finding the longitude, which enables the mariner to aſcertain with certainty his ſituation on the unvaried face of the ocean.

Hadley's quadrant or ſextant is the only known inſtrument on which the mariner can depend, for determining with accuracy and preciſion his latitude and longitude. It is to the uſe of this inſtrument that navigation is indebted for the very great and rapid advances it has made within theſe few years. It is eaſy to manage, and of extenſive uſe, requiring no peculiar ſteadineſs of hand, nor any ſuch fixed baſis as is neceſſary to other aſtronomical inſtruments.

Mankind are ever deſirous of knowing to whom they are indebted for any peculiar or uſeful diſcovery: it is the tribute of gratitude, and a reward to merit. In the preſent inſtance there is no difficulty in giving the information, the reſpective claims of the inventors are eaſily decided, and the Britiſh ſailor will learn with

 pleaſure

pleaſure that his countrymen were the inventors of this uſeful inſtrument. The firſt thought originated withthe celebrated Dr. Hooke, it was completed by Sir Iſaac Newton, and publiſhed by Mr. Hadley.

Notwithſtanding, however, the manifeſt ſuperiority of this inſtrument over thoſe that were in uſe at the time of it's publication, it was many years before the ſailors could be perſuaded to adopt it, and lay aſide their imperfect and inaccurate inſtruments: ſo great is the difficulty to remove prejudice, and emancipate the mind from the ſlavery of opinion.

No inſtrument has undergone, ſince the original invention, more changes than the quadrant of Hadley; of the various alterations, many had no better foundation than the caprice of the makers, who by theſe attempts have often rendered the inſtrument more complicated in conſtruction, and more difficult in uſe, than it was in it's original ſtate.

ESSENTIAL PROPERTIES OF HADLEY'S QUADRANT.

It is not my intention under this head to enumerate all the advantages of this inſtrument; but barely to point out one or two of thoſe eſſential properties which diſtinguiſh it from every other inſtrument of the kind, and rank it among one of the greateſt improvements in the practice of navigation.

It is an eſſential property of this inſtrument, derived from the laws of reflection, that half degrees on the arch anſwer to whole ones in the angles meaſured: hence an octant, or the eighth part of a circle, or 45 degrees on

 the

the arch, ſerves to meaſure 90 degrees; and ſextants will meaſure an angular diſtance of 120 degrees, though the arch of the inſtrument is no more than 60 degrees. It is from this property that foreigners term that inſtrument an octant, which we uſually call a quadrant, and which in effect it is. This property reduces indeed conſiderably the bulk of the inſtrument; but at the ſame time it calls for the utmoſt accuracy in the diviſions, as every error on the arch is doubled in the obſervation.

Another eſſential, and indeed an invaluable property of this inſtrument, whereby it is rendered peculiarly advantageous in marine obſervations, is, that it does not require any peculiar ſteadineſs of the hand, nor is liable to be diſturbed by the ſhip's motion; for provided the mariner can ſee diſtinctly the two objects in the field of his inſtrument, no motion nor vacillation of the ſhip will injure his obſervation.

Thirdly, the errors to which it is liable are eaſily diſcovered, and readily rectified, while the application and uſe of it is facile and plain.

DESCRIPTION OF HADLEY'S QUADRANT.

Fig. 1, repreſents a quadrant, or octant, of the common conſtruction. The following parts are thoſe which require the particular attention of the obſerver.

I.	B C	the arch.
II.	D	the index, a b the nonius ſcale.
III.	E	the index-glaſs.
IV.	F	the fore horizon-glaſs.
V.	G	the back horizon-glaſs.

VI.

VI. K the dark glaſſes or ſcreens.
VII. H I the vanes or ſights.

OF THE QUADRANT.

The quadrant conſiſts of an arch B C, firmly attached to two radii, or bars, A B A C, which are ſtrengthened and bound together by the two braces L M.

OF THE INDEX.

The index D is a flat bar of braſs, that turns on the center of the octant; at the lower end of the index there is an oblong opening, to one ſide of this opening the nonius ſcale is fixed, to ſubdivide the diviſions of the arch; at the bottom or end of the index there is a piece of braſs, which bends under the arch, carrying a ſpring to make the nonius ſcale lie cloſe to the diviſions; it is furniſhed with a ſcrew to fix the index in any deſired poſition.

The beſt inſtruments have an adjuſting ſcrew fitted to the index, that it may be moved more ſlowly, and with greater regularity and accuracy than by the hand. It is proper, however, to obſerve, that the index muſt be previouſly fixed near it's right poſition by the above-mentioned ſcrew. Before the adjuſting ſcrew is put in motion, the circular arches on the arch of the quadrant are drawn from the center on which the index turns: the ſmalleſt eccentricity in the axis of the index would be productive of conſiderable errors.

It is the poſition of the index on the arch, after an obſervation, which points out the number of degrees and minutes contained in the obſerved angle.

OF THE INDEX-GLASS E.

Upon the index, and near it's axis, is fixed a plane ſpeculum, or mirror of glaſs quickſilvered. It is ſet in a braſs frame, and is placed ſo that the face of it is perpendicular to the plane of the inſtrument; this mirror being fixed to the index, moves along with it, and has it's direction changed by the motion thereof.

This glaſs is deſigned to receive the image of the ſun, or any other object, and reflect it upon either of the two horizon glaſſes, according to the nature of the obſervation.

The braſs frame with the glaſs is fixed to the index by the ſcrew c; the other ſcrew ſerves to re-place it in a perpendicular poſition, if by any accident it has been deranged, as will be ſeen hereafter.

OF THE HORIZON-GLASSES F, G.

On the radius AB of the octant are two ſmall ſpeculums. The ſurface of the upper one is parallel to the index-glaſs, when the counting diviſion of the index is at o on the arch; but the ſurface of the lower one is perpendicular to the index-glaſs when the index is at o degrees on the arch: theſe mirrors receive the reflected rays from the object, and tranſmit them to the obſerver,

The

The horizon-glaſſes are not entirely quickſilvered; the upper one, F, is only ſilvered on it's lower part, or that half next the quadrant, the other half being tranſparent, and the back part of the frame is cut away, that nothing may impede the ſight through the unſilvered part of the glaſs. The edge of the foil of this glaſs is nearly parallel to the plane of the inſtrument, and ought to be very ſharp, and without a flaw.

The other horizon-glaſs is ſilvered at both ends; in the middle there is a tranſparent ſlit, through which the horizon may be ſeen.

Each of theſe glaſſes is ſet in a braſs frame, to which there is an axis; this axis paſſes through the wood-work, and is fitted to a lever on the under ſide of the quadrant; by this lever the glaſs may be turned a few degrees on it's axis, in order to ſet it parallel to the index-glaſs. The lever has a contrivance to turn it ſlowly, and a button to fix it. To ſet the glaſſes perpendicular to the plane of the quadrant, there are two ſunk ſcrews, one before and one behind each glaſs; theſe ſcrews paſs through the plate on which the frame is fixed, into another plate, ſo that by looſening one, and tightening the other of theſe ſcrews, the direction of the frame, with it's mirror, may be altered, and thus be ſet perpendicular to the plane of the inſtrument.

OF THE SHADES, OR DARK GLASSES, K.

There are two red or dark glaſſes, and one green one; they are uſed to prevent the bright rays of the ſun, or the glare of the moon, from hurting the eye at the time of obſerva-

observation. They are each of them ſet in a braſs frame, which turns on a center, ſo that they may be uſed ſeparately, or together, as the brightneſs of the ſun may require. The green glaſs may be uſed alſo alone, if the ſun be very faint; it is alſo uſed for taking the altitude of the moon, and in aſcertaining her diſtance from a fixed ſtar.

When theſe glaſſes are uſed for the fore obſervation, they are fixed as in fig. 1; when uſed for the back obſervation, they are removed to N.

OF THE TWO SIGHT VANES H, I.

Each of theſe vanes is a perforated piece of braſs, deſigned to direct the ſight parallel to the plane of the quadrant. That which is fixed at I is uſed for the fore, the other for the back obſervation.

The vane I has two holes, one exactly at the height of the quickſilvered edge of the horizon glaſs, the other ſomewhat higher, to direct the ſight to the middle of the tranſparent part of the mirror.

OF THE DIVISIONS ON THE LIMB OF THE QUADRANT, AND OF THE NONIUS ON THE INDEX.

Before any obſerver can uſe his quadrant, he muſt become acquainted with the diviſions on the limb or arch, and of thoſe on the ſmall arch or nonius, which is carried by the index, and learn to read them off, or eſtimate them with eaſe and accuracy.

The

The limb is divided from right to left, into 90 primary divisions, which are to be considered as degrees, and each degree is subdivided into three equal parts, which are therefore of 20 minutes each; the odd minutes are obtained by means of the scale of divisions, which are placed on the small arch of the index.

OF THE NONIUS, OR SUBDIVIDING SCALE.

We have here to describe the nature and use of that admirable contrivance commonly called a nonius. It depends on this very simple circumstance, that if any line be divided into equal parts, the length of each part will be greater, the fewer divisions there are in the original line; on the contrary, the length of each division will be less, in proportion as the divisions are more numerous.

Thus it may be observed, that the two extreme strokes on the nonius contains 7 degrees, or 21 of the aforementioned small divisions, but that it is divided only into 20 parts; each of these parts will be longer than those on the arch, in the proportion of 21 to 20; that is to say, they will be one-twentieth part, or one minute longer, than the divisions on the arch; consequently, if the first, or index division of the nonius, be set precisely opposite to any degree, the relative position of the nonius and the arch must be altered 1 minute before the next division on the nonius will coincide with the next division on the arch, the second division will require a change of 2 minutes, the third of 3 minutes, and so on, till the 20th stroke on the nonius arrive at the next 20 minutes on the arch; the index division will then have moved

exactly 20 minutes from the divifion whence it fet out, and the intermediate divifions of each minute have been regularly pointed out by the divifions of the nonius.

To render this ftill plainer, we muft obferve that the index, or counting divifion of the nonius, is diftinguifhed by the mark 0, which is placed on the extreme right hand divifion, the numbers running regularly on thus, 20, 15, 10, 5, 0.

The index divifion points out the entire degrees and odd twenty minutes, fubtended by the objects obferved; but the intermediate divifions are fhewn by the other ftrokes of the nonius: thus, look among the ftrokes of the nonius for one that ftands directly oppofite to, or perfectly coincident with fome one divifion on the limb; this divifion reckoned on the nonius, fhews the number of minutes to be added to what is pointed out by the index divifion.

To illuftrate this fubject, let us fuppofe two cafes. The firft, when the index divifion perfectly coincides with a divifion on the limb of the quadrant: here there is no difficulty, for at whatfoever divifion it is, that divifion indicates the required angle. If the index divifion ftands at 40 degrees, 40 degrees is the meafure of the required angle. If it coincides with the next divifion beyond 40 on the right hand, 40 deg. 20 min. is the angle. If with the fecond divifion beyond 40, then 40 deg. 40 min. is the angle, and fo in every other inftance.

The fecond cafe is, when the index line does not coincide with any divifions on the limb. We are, in this inftance, to look for a divifion on the nonius, that fhall

ftand

ſtand directly oppoſite to one on the limb, and that diviſion gives us the odd minutes, to be added to thoſe pointed out by the index diviſion; thus, ſuppoſe the index diviſion does not coincide with 40 degrees, but that the next diviſion to it is the firſt coincident diviſion, then is the required angle 40 degrees 1 minute. If it had been the ſecond diviſion, the angle would have been 40 deg. 2 min. and ſo on to 20 min. when the index diviſion coincides with the firſt 20 min. from 40 degrees. Again, let us ſuppoſe the index diviſion to ſtand between 30 deg. and 30 deg. 20 min. and that the 16th diviſion on the nonius coincides exactly with a diviſion on the limb, then is the angle 30 deg. 16 min. Further, let the index diviſion ſtand between 35 deg. 20 min. and 35 deg. 40 min. and at the ſame time the 12th diviſion on the nonius ſtands directly oppoſite to a diviſion on the arch, then will the angle be 35 deg. 32 min.

A GENERAL RULE FOR KNOWING THE VALUE OF EACH DIVISION, ON ANY NONIUS WHATSOEVER.

As the mariner may have occaſion for eſtimating a nonius diviſion, differing from that already explained, I thought I ſhould be doing him a ſervice, by giving him the following rule.

1. Find the value of each of the diviſions, or ſubdiviſions, of the limb to which the nonius is applied. 2. Divide the quantity of minutes or ſeconds thus found, by the number of diviſions on the nonius, and the quotient will give the value of the nonius diviſion.

Thus ſuppoſe each ſubdiviſion of the limb be 30 minutes, and that the nonius has 15 diviſions, then $\frac{30}{15}$ gives 2 minutes for the value of the nonius. If the nonius has 10 diviſions, each one would give 3 minutes. If the limb was divided to every 12 minutes, and the nonius to 24 parts, then 12 minutes, or 720 ſeconds, divided by 24, give 30 ſeconds for the value required.

OF THE ARCH OF EXCESS.

Thoſe diviſions on the arch which go from 0 towards the right hand, are the diviſions on the arch, called the arch of exceſs. If an angle is meaſured on this arch, the numbers on the nonius are to be read in a contrary order, as if they had ſtood thus, 0, 5, 10, 15, 20.

Many writers have affected of late, in oppoſition to general practice, to term that ſpecies of diviſion which we have here called nonius, a vernier, under the idea that Vernier was the inventor; but it does not appear that the claims of Vernier are better founded than thoſe of Nonius. That Clavius, the Jeſuit, was the inventor, is clear from a work of his which was printed in 1611: whereas the work of Vernier was not printed till 1631.

Whoever has paid any attention to human life, muſt have perceived that affectation and enthuſiaſm belong to every claſs of it; and will find as much of the firſt among aſtronomers, as among fops and beaus; and as much of the ſecond, combined with bigotry, among philoſophers, as in the ſectarian ſpirit of the field preacher. There is abundant reaſon to wiſh, that in this enlightened age men would endeavour to ſeek and promote truth for truth's

ſake,

sake, and not suffer themseves to be led away, in any respect, by the authority of names, or veneration for adopted opinions.

Directions to Hold the Instrument.

It is recommended to support the weight of the instrument by the right hand, and reserve the left to govern the index. Place the thumb of the right hand against the edge of the quadrant, under the swelling part on which the fore sight I stands, extending the fingers across the back of the quadrant, so as to lay hold on the opposite edge, placing the fore finger above, and the other fingers below the swelling part, or near the fore horizon glass: thus you may support the instrument conveniently, in a vertical position, by the right hand only; by resting the thumb of the left hand against the side, or the fingers against the middle bar, you may move the index gradually either way.

In the back observation, the instrument should be supported by the left hand, and the index be governed by the right.

Of the Axis of Vision, or Line of Sight.

Of the two objects which are made to coincide by this instrument, the one is seen directly by a ray passing through, the other by a ray reflected from the same point of the horizon glass to the eye. This ray is called the visual ray; but when it is considered merely as a line

drawn from the middle of the horizon glaſs to the eye hole of the ſight vane, it is called the axis of viſion.

The axis of the tube, or teleſcope, uſed to direct the ſight, is alſo called the axis of viſion.

The quadrant, if it be held as before directed, may be eaſily turned round between the fingers and thumb, and thus nearly on a line parallel to the axis of viſion.

OF THE NECESSARY ADJUSTMENTS.

It is a peculiar excellence of Hadley's quadrant, that the errors to which it is liable are eaſily detected, and ſoon rectified; the mariner may, therefore, if he will be attentive, always put his inſtrument in a ſtate fit for accurate obſervation. The importance of this inſtrument to navigation is ſelf-evident; yet much of this importance depends on the accuracy with which it is made, and the neceſſary attention of the obſerver; and one would hardly think it poſſible that any mariner would, to ſave the trifling ſum of one or two guineas, prefer an imperfect inſtrument to one that was rightly conſtructed and accurately made; or that any conſideration ſhould induce him to neglect the adjuſtments of an inſtrument, on whoſe truth he is ſo highly intereſted. But ſuch is the nature of man! he is too apt to be laviſh on baubles, and penurious in matters of conſequence; active about trifles, indolent where his welfare and happineſs are concerned. The adjuſtments for the fore obſervation are, 1. To ſet the fore horizon glaſs parallel to the index glaſs; this adjuſtment is of the utmoſt importance, and ſhould always be made previous to actual obſervation.

The second is, to see that the plane of this glass is perpendicular to the plane of the quadrant. 3. To see that the index glass is perpendicular to the plane of the instrument.

TO ADJUST THE FORE HORIZON GLASS.

This rectification is deemed of such importance, that it is usual to speak of it as if it included all the rest, and to call it ADJUSTING THE INSTRUMENT. In other words, so to place the horizon glass, that the index may shew upon the arch the true angle between the objects; for this purpose, set the index line of the nonius exactly against o on the limb, and fix it there by the screw at the under side. Now look through the sight I at the edge of the sea, or some very distant object. The edge of the sea will be seen directly through the unsilvered part of the glass, but by reflection in the silvered part. If the horizon in the silvered part exactly meets, and forms one continued line with that seen through the unsilvered part, then is the instrument said to be adjusted, and the horizon glass is parallel to the index glass.

But if the horizons do not coincide, then loosen the milled nut on the under side of the quadrant, and turn the horizon glass on it's axis, by means of the adjusting lever, till you have made them perfectly coincide; then fix the lever firmly in the situation thus obtained, by tightening the milled nut. This adjustment ought to be repeated before and after every astronomical observation.

So

So important is this rectification, that experienced observers, and those who are desirous of being very accurate, will not be content with the preceding mode of adjustment, but re-examine it, and if they find any error, allow for it in their calculations. This is usually called finding the index error.

TO FIND THE INDEX ERROR.

Adjust the instrument as near as possible by the lever, agreeable to the foregoing directions; then move the index forwards, and afterwards bring it back, so that the edge of the sea seen in the silvered part of the mirror, may join exactly to, and form one continued line with the edge of the sea seen through the transparent part of the glass: when this is done, observe whether the index division on the nonius agrees with the o line on the arch; if it do not, the number by which they differ is a quantity to be added to the observation, if the index line is beyond the o on the limb; but if the index line of the nonius stands between o and 90 degrees, then this error is to be subtracted from the observation.*

That part of the arch beyond o, towards the right hand, is called the arch of excess; the nonius must be read the contrary way, or which is the same thing, you may read them off in the usual way, and then their complement

* This adjustment may be made more accurately, or the error better found, by using the sun instead of the horizon; but this method requires another set of dark glasses, to darken the direct rays of the sun; such a set is applied to the best instruments, and this method of adjustment is explained in the following description of the sextant.

plement to 20 min. will be the real number of degrees and minutes to be added to the obſervation.

To make the Index Glass and fore Horizon Glass perpendicular to the Plane of the Instrument.

Though theſe adjuſtments are neither ſo neceſſary nor important as the preceding one, yet as after being once performed they do not require to be repeated for a conſiderable time, and as they add to the accuracy of obſervation, they ought not to be neglected; and further, a knowledge of them enables the mariner to examine and form a proper judgment of his inſtrument.

To adjust the Index Glass.

Method 1. By means of the two adjuſting tools, repreſented at fig. 2 and 3, which are two wooden frames, with two lines on each, exactly at the ſame diſtance from the bottom.

Place the quadrant in an horizontal poſition on a table, put the index about the middle of the arch, turn back the dark glaſſes, place one of the above-mentioned tools near one end of the arch, the other at the oppoſite end, the ſide with the lines towards the index glaſs; then look down the index glaſs, directing the ſight parallel to the plane of the inſtrument, you will ſee one of the tools by direct viſion, the other by reflection in the mirror; by moving the index a little, they may be brought exactly together. If the lines coincide, the mirror is rightly fixed;

fixed; if not, it must be restored to it's proper situation by loosening the screw, and tightening the screw, or vice versa, by tightening the screw and loosening the screw.

Method 2. Hold the quadrant in an horizontal position, with the index glass close to the eye; look nearly in a right line down the glass, and in such manner, that you may see the arch of the quadrant by direct view, and by reflection at the same time. If they join in one direct line, and the arch seen by reflection forms an exact plane with the arch seen by direct view, the glass is perpendicular to the plane of the quadrant; if not, the error must be rectified, by altering the position of the screws behind the frame, as directed above.

TO ASCERTAIN WHETHER THE FORE HORIZON GLASS BE PERPENDICULAR TO THE PLANE OF THE INSTRUMENT.

Having adjusted the index and horizon glasses agreeable to the foregoing directions, set the index division of the nonius exactly against o on the limb; hold the plane of the quadrant parallel to the horizon, and observe the image of any distant object at land, or at sea the horizon itself; if the image seen by reflection be higher than the object itself seen directly, release the fore screw, and tighten the back screw, and vice versa, if the image seen by reflection be lowest: and thus proceed till both are of an equal height, and that by moving the index you can make both objects appear as one.

Or;

Or: Adjuſt the fore horizon glaſs as directed in page 21; then incline the quadrant on one ſide as much as poſſible, provided the horizon continues to be ſeen in both parts of the glaſs. If, when the inſtrument is thus inclined, the edge of the ſea continues to form one unbroken line, the quadrant is perfectly adjuſted; but if the reflected horizon be ſeparated from that ſeen by direct viſion, the ſpeculum is not perpendicular to the plane of the quadrant. And if the obſerver is inclined to the right, with the face of the quadrant upwards, and the reflected ſea appears higher than the real ſea, you muſt ſlacken the ſcrew before the horizon glaſs, and tighten that which is behind it; but if the reflected ſea appears lower, the contrary muſt be performed.

Care muſt be always taken in theſe adjuſtments to looſen one ſcrew before the other is ſcrewed up, and to leave the adjuſting ſcrews tight, or ſo as to draw with a moderate force againſt each other.

This adjuſtment may be alſo made by the ſun, moon, or ſtar; in this caſe the quadrant may be held in a vertical poſition; if the image ſeen by reflection appears to the right or left of the object ſeen directly, then the glaſs muſt be adjuſted as before by the two ſcrews.

To take the Altitude of the Sun by the fore Observation.

Obſervations taken by means of the fore horizon glaſs are called fore obſervations, becauſe in them both objects are before the obſerver.

Previous to every obſervation, the inſtrument ſhould be examined, in order to ſee whether the index or horizon glaſſes be firm, or whether any of the ſcrews be looſe; the horizon glaſs muſt alſo be adjuſted.

One or two of the dark glaſſes ſhould be placed before the horizon glaſs, always proportioning the ſtrength of the ſhades to the brightneſs of the ſun's rays, that the image may be looked at without injury to the eye.

Hold the quadrant (in a vertical poſition, the arch downwards) either by the braces or the radii, as may be moſt convenient, or ſtill better, according to the foregoing directions. Let the eye be at the upper hole in the ſight vane, and the lower part of the limb againſt the breaſt.

Turn yourſelf towards the ſun, and direct the ſight to that part of the horizon that lies directly under it, keeping the quadrant as near as you can judge in a plane paſſing through the ſun's center and the neareſt part of the horizon, moving at the ſame time the index with the left hand, ſo as to bring the image of the ſun down toward the horizon; then ſwing the quadrant round in a line parallel to the line of ſight; by this means the image of the ſun may be made to deſcribe the arch of a circle, with the convex ſide downwards: now if that edge of the ſun which is obſerved, juſt grazes upon the horizon, or that the horizon juſt touches it like a tangent, without cutting it, the obſervation is rightly made, and the degrees and minutes pointed out by the nonius on the arch, ſhew the apparent altitude of the ſun. But if the ſun's edge dip below, or cut the horizon, the index muſt be moved backward; if, on the contrary, it falls

falls ſhort of it, the index muſt be moved forward, until it juſt grazes the horizon.

Dr. Maſkelyne gives the following advice: that in taking the ſun's altitude, the obſerver ſhould turn his quadrant round upon the axis of viſion, and at the ſame time turn himſelf upon his heel, ſo as to keep the ſun always in that part of the horizon glaſs which is at the ſame diſtance as the eye from the plane of the quadrant; and that unleſs care be taken to obſerve the objects in the proper part of the horizon glaſs, the meaſured angles cannot be true. In this method the reflected ſun will deſcribe an arch of a parallel circle round the true ſun, whoſe convex ſide will be downwards, and conſequently when by moving the index the loweſt point of the arc is made to touch the horizon, the quadrant will ſtand in a vertical plane, and the altitude above the viſible horizon will be properly obſerved.

Great care ſhould be taken that the ſituation of the index be not altered before the quantity it makes is read off.

The obſerved or apparent altitude of the ſun requires three corrections, in order to obtain the true altitude of the ſun's center above the horizon.

1. The firſt correction is to obtain the obſerved altitude of the ſun's center.

All aſtronomical calculations, reſpecting the heavenly bodies, are adapted to their centers; but in taking altitudes of the ſun, it is uſual to bring his lower limb in apparent contact with the horizon. In this caſe it is evident, that a quantity equal to the ſemidiameter of the ſun muſt be added to the obſerved altitude, to give the

 altitude

altitude of his center. But if on any occaſion, as from clouds, the altitude of the upper limb be taken, the ſemidiameter of the ſun muſt be ſubtracted.

The mean ſemidiameter of the ſun is 16 minutes, which may be taken as a conſtant quantity in common obſervations, as the greateſt variation from this quantity ſcarcely exceeds one quarter of a minute.

2. The ſecond correction is, to rectify the errors ariſing from refraction.

One of the principal objects of aſtronomy is, to fix the ſituation of the ſeveral heavenly bodies. It is neceſſary, as a firſt ſtep, to underſtand the cauſes which occaſion a variation in the appearance of the place of thoſe objects, and make us ſuppoſe them to be in a different ſituation from what they really are: among theſe cauſes refraction is to be reckoned.*

The rays of light, in their paſſage from the celeſtial luminaries to our eyes, are bent from their true direction by the atmoſphere; this bending is called refraction; and they are more or leſs refracted, according to the degree of obliquity with which they enter the atmoſphere, that is, according to the altitude of the object; from this cauſe, their apparent altitude is always too great; the quantity to be ſubtracted from the obſerved altitude is to be found in a table ſubjoined to this tract.

The following pleaſing and eaſy experiment will give the reader an idea of what is meant by the refraction of the rays of light; a wonderful property to which we are indebted for all the advantages of viſion, and the aſſiſtance we receive from teleſcopes, &c.

Experiment.

* Adams's Aſtronomical and Geographical Eſſays.

Experiment. Into any ſhallow veſſel (a baſon) put a ſhilling, and retire to ſuch a diſtance as that you can juſt ſee the farther edge of the ſhilling, but no more; let the veſſel, the ſhilling, and your eye, remain in the ſame ſituation, while an aſſiſtant fills up the veſſel with water, and the whole ſhilling will become viſible, the rays coming from the ſhilling being lifted or bent upwards in their paſſage through the water. For the ſame reaſon, a ſtrait ſtick put partly into water appears bent.

3. The third correction is for the dip or depreſſion of the horizon.

The dip of the horizon is the quantity that the apparent horizon appears below the true horizon, and is principally occaſioned by the height of the obſerver's eye above the water; for as he is elevated above the level of the ſea, the horizon he views is below the true one, and the obſerved altitude is too great, by a quantity proportioned to the height of the eye above the ſea: the quantity to be ſubtracted from the altitude will be found in a table ſubjoined to this tract.

Mr. Nicholſon ſays, that obſervers at ſea generally chuſe to ſtand in the ſhip's waiſt when they take altitudes, becauſe the height of the eye above the water is not ſo much altered by the motion of the ſhip; but this is of no conſequence, for in rough weather, the edge of the ſea beheld from a ſmall elevation is made uneven by waves whoſe altitudes amount to 2 or 3 minutes, or more; which circumſtance produces as great an uncertainty as the riſe and fall of the object ſeen from the poop, when the ſhip pitches. Theſe are minute cauſes of error, but

not to be disregarded by those who wish to obtain habits of accuracy and exactness.*

MERIDIONAL ALTITUDES.

The meridian altitude of the sun † is found by attending a few minutes before noon, and taking his altitude from time to time: when the sun's altitude remains for some time without any considerable increase, the observer must be attentive to mark the coincidence of the limb of the sun with the horizon, till it perceptibly dips below the edge of the sea. The quantity thus observed is the meridional altitude.

TO TAKE THE ALTITUDE OF A STAR.

Before an observer attempts to take the altitude of a star, it will be proper for him to exercise himself by viewing a star with the quadrant, and learning to follow the motion of the reflected image without losing it, lest he should take the image of some other star instead of that whose altitude he is desirous to obtain. His quadrant being properly adjusted, let him turn the dark glasses out of the way, and then,

1. Set the index of the nonius to the o line of the limb.

2. Hold the quadrant in a vertical position, agreeable to the foregoing directions.

3. Look

* Nicholson's Navigator's Assistant.

† At places where it rises and sets.

3. Look through the ſight vane and the tranſparent part of the horizon glaſs, ſtrait up to the ſtar, which will coincide with the image ſeen in the ſilvered part, and form one ſtar; but as ſoon as you move the index forwards, the reflected image will deſcend below the real ſtar; you muſt follow this image, by moving the whole body of the quadrant downwards, ſo as to keep it in the ſilvered part of the horizon glaſs as the motion of the index depreſſes it, until it comes down exactly to the edge of the horizon.

It is reckoned better to obſerve cloſe than open, that is, to be well aſſured that the objects touch each other; and this opinion is well founded, as many perſons are near-ſighted without knowing it, and ſee diſtant objects a little enlarged, by the addition of a kind of penumbra, or indiſtinct ſhading off into the adjacent air.

There are but two corrections to be made to the obſerved altitude of a ſtar, the one for the dip of the horizon, the other for refraction.

RULES FOR FINDING THE LATITUDE; THE SUN'S ZENITH, DISTANCE, AND DECLINATION AT NOON BEING GIVEN.

The firſt ſubject for conſideration is, whether the ſun's declination be north or ſouth: and ſecondly, whether the required latitude be north or ſouth. If the latitude or declination be both north or both ſouth, they are ſaid to be of the ſame denomination; but if one be north and the other ſouth, they are ſaid to be of different denomina-

denominations. Thirdly, take the given altitude from 90 to obtain the zenith distance.

Rule 1. If the zenith distance and declination be of the same name, then their difference will give the latitude, whose denomination is the same with the declination, if it be greater than the zenith distance; but the latitude is of a contrary denomination, if the zenith distance be less than the declination.

Rule 2. If the zenith distance and declination have contrary names, their sum shews the required latitude, whose name will be the same as the declination.

Or: By the two following rules you may find the latitude of the place from the altitude and declination given.

Rule 1. If the altitude and declination are of different names, that is, the one north the other south, add 90 degrees to the declination; from that sum subtract the meridian altitude, the remainder is the latitude, and is of the same name as the declination.

Rule 2. If the meridian altitude and declination are of the same denomination, that is, both north or both south, then add the declination and altitude together, and subtract that sum from 90 degrees, if it be less, and the remainder will be the latitude, but of a contrary name. But if the sum exceeds 90 degrees, the excess will be the latitude, of the same name with the declination and altitude.

EXAMPLES FOR FINDING THE LATITUDE BY MERIDIAN OBSERVATION. *

Example 1. Being at ſea, July 29, 1779, the meridian altitude of the ſun's lower limb was obſerved to be 34° 10′ N. the eye of the obſerver being 25 feet above the ſea. The latitude of the place is required.

The ſun's declination for the third year† after leap year on July 29, is found in Table III. to be 18° 46′ N. the dip for 25 feet elevation is 5 minutes, the refraction for 34° is 1 minute, therefore

Altitude of ſun's lower limb	34°	10′	N.
Add ſemidiameter		16	
	34	26	
Subtract dip and refraction		6	
Correct altitude	34	20	
Zenith diſtance or co-alt.	55	40	
Subtract declination	18	46	N.
Remains latitude	36	54	S. or of the contrary name to the declin.

Example

* Nicholſon's Navigator's Aſſiſtant.

† The annual courſe of the ſeaſons, or the natural year, conſiſting of nearly 365 days 6 hours, and the current year being reckoned 365 days, it is evident that one whole day would be loſt in four years if the ſix hours were conſtantly rejected. To avoid this inconvenience, which, if not attended to, would cauſe the ſeaſons to ſhift in proceſs of time through all the months of the year, an additional day is added to the month of February, every fourth year; this fourth year is termed leap year, and is found

by

Example 2. October 26, 1780, sun's meridional altitude, lower limb 62 09 S. required the latitude. Height of the eye 30 feet.

1780 is leap year, and the sun's declination in October 26, is 12° 45′ S. The dip for 30 feet elevation is 6 minutes, the refraction for 62° is ½ minute. Therefore,

Sun's apparent alt. l. l.	62° 09′ S.	
+ semidiam.—dip and refrac.	9 ½	
Correct alt.	62 18 ½	
Zenith dis.	27 41 ½ S.	
Sun's declination	12 45 S.	
Difference is lat.	14 56 ½ N.	or of the contrary name.

Example 3. Jan. 7, 1776, altitude of sun's lower limb, at noon 87° 10′ S. height of the eye 30 feet, required the latitude.

Sun's apparent alt. l. l.	87° 10	
+ semidiam.—dip.	10	refraction being inconsiderable
Correct alt.	87 20	
Zenith distance	2 40 S.	
Sun's declinat.	19 13 N.	
Sum is latitude	21 53 N.	

Example

by dividing the year of our Lord by 4; leap year leaves no remainder; other years are called the first, second, or third years after leap year, according as the remainder is 1, 2, or 3.

Example 4. In the year 1778, July 30, the ſun's meridian altitude lower limb was 84° 10′ N. Required the latitude. The height of the eye being 30 feet:

Sun's apparent alt. l. l.	84° 10′	
+Semidiam.—dip.	10	
Correct alt.	84 20	
Zenith diſt.	5 40	N.
Sun's declination	18 28	N.
Difference is lat.	12 48	N.

Example 5. Being at ſea in the year 1777, cloſe weather prevented the meridian obſervation of the ſun, but the night proving clear, the northernmoſt ſtar in the ſquare of the Great Bear was obſerved to come to it's leaſt altitude 30° 10′.—Required the latitude: the height of the eye being 20 feet.

Star's altitude apparent	30° 10′	
—Dip and refraction	6 ½	
Correct altitude	30 03 ½	
Star's co-declination	27 03	N.
Sum is latitude	57 06 ½	N. by Prob. II.

Example 6. June 11, 1770, the ſun's meridian altitude of the upper limb below the pole was obſerved to be 2° 08′. The height of the obſerver's eye being 16 feet —Required the latitude.

Sun's apparent altitude upper limb	2°	08′
—dip, refraction, and ſemidiam.		38
Correct alt.	1	30
Sun's declin. 23° 08′ N. it's comp.	66	52 N.
Sum is latitude	68	22 N.

OF THE BACK OBSERVATION.

In quadrants of the common conſtruction the fore obſervation extends only to the admeaſurement of angles not exceeding 90 degrees: in order to make it uſeful as far as 180 degrees, the horizon glaſs and it's ſight are added.

But as there are not many occaſions at ſea for making uſe of the back obſervation; and as it is far from being ſo eaſy in practice as the fore, and the adjuſtments are very difficult, mariners ſeldom pay much attention to it, though a little attention and exerciſe would probably ſoon ſurmount thoſe difficulties.

OF THE ADJUSTMENTS.

The back obſervation is ſo called, becauſe the back is turned upon one of the two objects whoſe angular diſtance is to be meaſured.

The adjuſtment conſiſts in making the reflected image of the object behind the obſerver coincide with another ſeen directly before him, at the ſame time that the index diviſion of the nonius is directly againſt the o diviſion of the arch.

The

The method, therefore, of adjusting it, consists in measuring the distance of two objects nearly 180 degrees apart from each other; the arc passing through each object must be measured in both it's parts, and if the sum of the parts be 360 degrees, the speculums are adjusted; but if not, the axis of the horizon glass must be moved till this sum is obtained.

Set the index as far behind o as twice the dip of the horizon amounts to; then look at the horizon through the slit near G, and at the same time the opposite edge of the sea will appear by reflection inverted, or upside down. By moving the lever of the axis (if necessary), the edges may be made to coincide, and the quadrant is adjusted.

There is but one position in which the quadrant can be held with the limb downwards, without causing the reflected horizon to cross the part seen by direct vision.

If, on trial, this position be found to be that in which the plane of the quadrant is perpendicular to the horizon, no farther adjustment is necessary, than the fore-mentioned one; but if the horizons cross each other when the quadrant is held upright, observe which part of the reflected horizon is lowest.

If the right-hand part be lowest, the sunk screw which is before the horizon-glass must be tightened after slackening that which is behind the glass; but if the right hand is highest, the contrary must be performed: this adjustment is, however, of much less importance than the preceding, as it does not so much affect the angle measured.

INCONVENIENCIES AND INACCURACIES OF THE BACK OBSERVATION.

The occaſions, in which the back obſervation is to be uſed, are when the altitude of the ſun or a ſtar are to be taken, and the fore horizon is broken by adjacent ſhores, or when the angular diſtance between the moon and ſun, or a ſtar, exceeds 90 degrees, and is required to be meaſured for obtaining the longitude at ſea: but there are objections to it's uſe in both caſes; for if a known land lie a few miles to the north or ſouthward of a ſhip, the latitude may be known from it's bearing and diſtance, without having recourſe to obſervation: and again, if the diſtance of the land in miles exceed the number of minutes in the dip, as is almoſt always the caſe in coaſting along an open ſhore, the horizon will not be broke, and the fore obſervation may be uſed; and laſtly, if the land be too near to uſe the fore obſervation, it's extreme points will in general be ſo far aſunder, as to prevent the adjuſtment, by taking away the back horizon. In the caſe of meaſuring the angular diſtances of the heavenly bodies, the very great accuracy required in theſe obſervations, makes it a matter of importance that the adjuſtments ſhould be well made, and frequently examined into. But the quantity of the dip is varied by the pitching and rolling of the ſhip; and this variation, which is perceptible in the meaſuring altitude by the fore obſervation, is doubled in the adjuſtment for the back obſervation, and amounts to ſeveral minutes. It is likewiſe exceeding difficult, in a ſhip under way, to hold the

quadrant for any length of time, ſo that the two horizons do not croſs each other, and in the night the edge of the ſea cannot be accurately diſtinguiſhed. All theſe circumſtances concur to render the adjuſtment uncertain; the fore obſervation is ſubject to none of theſe inconveniencies.*

* Nicholſon's Navigator's Aſſiſtant.

DESCRIP-

quadrant for any length of time, so that the two horizons do not [illegible] each other, and in the night the edge of the sea cannot be accurately distinguished. All these circumstances [illegible] to render the adjustment uncertain; the fore-observation is liable to none of these inconveniences.

[illegible]

DESCRIPTION, USE,

AND

METHOD OF ADJUSTING

HADLEY's SEXTANT,

AS MADE AND SOLD

By GEORGE ADAMS,
Mathematical Inſtrument Maker to His Majeſty, and Optician to His Royal Highneſs the Prince of Wales,
At TYCHO BRAHE's Head, No. 60, FLEET-STREET, LONDON.

AS the taking the angular diſtances of the moon and the ſun, or a ſtar, is one of the beſt and moſt accurate methods of diſcovering the longitude, it was neceſſary to enlarge the arch of the octant to the ſixth part of a circle; but as the obſervations for determining the longitude muſt be made with the utmoſt accuracy, the framing of the inſtrument was alſo altered, that it might be rendered more adequate to the ſolution of this important problem. Hence aroſe the preſent cenſtruction of the ſextant, in the deſcription of which, it is pre-

ſumed that the foregoing pages have been read, otherwiſe we ſhould be obliged to repeat the ſame obſervations.

Sextants are moſtly executed (ſome trifling variations excepted) on two plans; in the one, all the adjuſtments are left to the obſerver. He has it in his power to examine and rectify every part of his inſtrument: this mode is founded on this general principle, that the parts of no inſtrument can be ſo fixed as to remain accurately in the ſame poſition they had when firſt put out of the maker's hand; and that therefore the principal parts ſhould be made moveable, that their poſitions may be examined and rectified from time to time by the obſerver.

In the ſecond conſtruction, the principal adjuſtment, or that for the index error, is rejected; and this rejection is grounded upon two reaſons: 1. That from the nature of the adjuſtment it frequently happens that a ſextant will alter even during the time of an obſervation, without any apparent cauſe whatever, or without being ſenſible at what period of the obſervation ſuch alteration took place, and conſequently the obſerver is unable to allow for the error of adjuſtment.

2. That this adjuſtment is not in itſelf ſufficiently exact, it being impoſſible to adjuſt a ſextant with the ſame accuracy by the coincidence of two images of an object, as by the contact of the limbs thereof; and hence experienced and accurate obſervers have always directed the index error to be found, which renders the adjuſtment of the horizon glaſs, in this direction, uſeleſs; for it is eaſy to place it nearly parallel to the index glaſs, when the inſtrument is made, and then to fix it firmly in that poſition by ſcrews. The utility of this method is

is ſaid to be confirmed by experience: many ſextants, whoſe index had been determined previous to their being carried out to India, have been found to remain the ſame at their return.

Notwithſtanding the probable certainty of the horizon glaſs remaining permanently in it's ſituation, the obſerver ought from time to time to examine the index error of his inſtrument, to ſee if it remains the ſame; or to correct it, if any alteration ſhould have taken place.

One material point in the formation of a ſextant is ſo to conſtruct it, that it may ſupport it's own weight, and not be liable to bend by any inclination of the plane of the inſtrument, as every ſuch flexure would alter the relative poſition of the mirrors, on which the determination of an angle depends.

DESCRIPTION OF THE SEXTANT.

Fig. 4, repreſents the ſextant, ſo framed, as not to be liable to bend. The arch A A is divided into 120 degrees, each degree is divided into three parts, of courſe equal to 20 minutes, which are again ſubdivided by the nonius into every half minute, or 30 ſeconds: ſee the nature of the nonius, and the general rule for eſtimating the value thereof, in the preceding part of this pamphlet. Every ſecond diviſion, or minute, on the nonius is cut longer than the intermediate ones. The nonius is numbered at every fifth of theſe longer diviſions, from the right towards the left, with 5, 10, 15, and 20, the firſt

division towards the right hand being to be considered as the index division.

In order to observe with accuracy, and make the images come precisely in contact, an adjusting screw B is added to the index, which may thereby be moved with greater accuracy than it can by hand; but this screw does not act until the index is fixed by the finger screw C. Care should be taken not to force the adjusting screw when it arrives at either extremity of it's adjustment. When the index is to be moved any considerable quantity, the screw C at the back of the sextant must be loosened; but when the index is brought nearly to the division required, this back screw should be tightened, and then the index may be moved gradually by the adjusting screw.

There are four tinged glasses at D, each of which is set in a separate frame, that turns on a center: they are used to screen and save the eye from the brightness of the solar image and the glare of the moon, and may be used separately, or together, as occasion requires.

There are three more such glasses placed behind the horizon glass at E, to weaken the rays of the sun or moon, when they are viewed directly through the horizon glass. The paler glass is sometimes used in observing altitudes at sea, to take off the strong glare of the horizon.

The frame of the index glass I is firmly fixed by a strong cock to the center plate of the index. The horizon glass F is fixed in a frame that turns on the axes or pivots, which move in an exterior frame: the holes in which the pivots move may be tightened by four screws in the exterior frame; G is a screw by which the horizon glass

glaſs may be ſet perpendicular to the plane of the inſtrument; ſhould this ſcrew become looſe, or move too eaſy, it may be eaſily tightened by turning the capſtan-headed ſcrew H, which is on one ſide the ſocket, through which the ſtem of the finger-ſcrew paſſes.

The ſextant is furniſhed with a plain tube, fig. 7, without any glaſſes; and to render the objects ſtill more diſtinct, it has alſo two teleſcopes, one, fig. 5, repreſenting the objects erect, or in their natural poſition. The longer one, fig. 6, ſhews them inverted; it has a large field of view, and other advantages; and a little uſe will ſoon accuſtom the obſerver to the inverted poſition, and the inſtrument will be as readily managed by it as by the plane tube alone. By a teleſcope, the contact of the images is more perfectly diſtinguiſhed; and by the place of the images in the field of the teleſcope it is eaſy to perceive whether the ſextant is held in the proper place for obſervation. By ſliding the tube that contains the eye-glaſſes in the inſide of the other tube, the object is ſuited to different eyes, and made to appear perfectly diſtinct and well defined.

The teleſcopes are to be ſcrewed into a circular ring, at K; this ring reſts on two points againſt an exterior ring, and is held thereto by two ſcrews: by turning one or the other of theſe ſcrews, and tightening the other, the axis of the teleſcope may be ſet parallel to the plane of the ſextant. The exterior ring is fixed on a triangular braſs ſtem that ſlides in a ſocket, and by means of a ſcrew at the back of the quadrant, may be raiſed or lowered ſo as to move the center of the teleſcope to point to that part of the horizon-glaſs which ſhall be judged the moſt

fit

fit for obſervation. Fig. 8, is a circular head, with tinged glaſſes to ſcrew on the eye-end of either of the teleſcopes, or the plane tube. The glaſſes are contained in a circular plate, which has four holes; three of theſe are fitted with tinged glaſſes, the fourth is open. By preſſing the finger againſt the projecting edge of this circular plate, and turning it round, the open hole, or any of the tinged glaſſes, may be brought between the eye-glaſs of the teleſcope and the eye.

Fig. 9, a ſmall ſcrew-driver. Fig. 10, a manifying glaſs.

TO FIND THE INDEX ERROR OF THE SEXTANT.

To find the index error, is, in other words, to ſhew what number of degrees and minutes is indicated by the nonius when the direct and reflected images of an object coincide with each other.

The moſt general and moſt certain method of aſcertaining this error, is by meaſuring the diameter of the ſun, with the index on the arch of exceſs beyond the o of the limb, and alſo to the left of the o. If the numbers ſhewn on the arch be the ſame in both caſes, the glaſſes are truly parallel, and there is no index error; but if the numbers be different, then half the difference is the index error.

Several obſervations of the ſun's diameter being made in this manner, and a mean of the whole being taken, the index error may be found to very great exactneſs. In other words, the difference between the degree and minute ſhewn by the index: 1ſt, when the lower reflected limb of the ſun is exactly in contact with the upper limb

of the ſun; and ſecondly, when the upper edge of the image is in contact with the lower edge of the object, divided by 2 will be the index error.

If the number read with the index to the right of o on the arch is the greateſt, then the index error muſt be added to the number read off on the arch. But on the contrary, if the greateſt number be found when the index is to the left hand of o, then the index error muſt be ſubtracted from the number read off on the arch, in order to obtain the true angular diſtance between any two objects. It is, however, to be obſerved, that when the index is on the arch of exceſs, or to the right of o, the compliment of the numbers ſhewn on the nonius to 20 ought to be ſet down.

Example. Let the numbers of minutes ſhewn by the index to the right of zero, when the limbs of the two images are in contact, be 20 minutes, and the odd number ſhewn by the nonius be 5, the compliment of this to 20 is 15, which, added to 20, gives 35 minutes; and, ſecondly, that the number ſhewn by the index, when on the left of zero, and the oppoſite limbs are in contact, be 20 minutes, and by the nonius 9′ 30″, which makes together 29′ 30″; this ſubtracted from 35′ gives 5′ 30″, which divided by 2, gives 2′ 45″ for the index error; and becauſe the greateſt of the two numbers thus found was when the index was to the right of the o, this index error muſt be added to the number of degrees ſhewn on the arch at the time of an obſervation.

To

TO SET THE HORIZON GLASS PERPENDICULAR TO THE PLANE OF THE SEXTANT.

Direct the telescope to the sun, a star, or any other well-defined object, and bring the direct object and reflected image to coincide nearly with each other, by moving the index; then set the two images parallel to the plane of the sextant, by turning the screw, and the images will pass exactly over each other, and the mirror will then be adjusted in this direction.

TO SET THE AXIS OF THE TELESCOPE PARALLEL TO THE PLANE OF THE SEXTANT.

We have already observed, that in measuring angular distances the line of sight, or plane of observation, should be parallel to the plane of the instrument, as a deviation in that respect will occasion great errors in the observation, and this is most sensible in large angles: to avoid these, a telescope is made use of, in whose field there are placed two wires parallel to each other, and equidistant from the center. By these wires, when they are placed parallel to the plane of the sextant, the observer can, not only determine the center of the field or axis of the telescope, but also properly adjust the axis of the telescope.

TO ADJUST THE TELESCOPE.

Screw the telescope in it's place, and turn the eye-tube round, that the wires in the focus of the eye-glass may be

parallel

parallel to the plane of the instrument; then seek two objects, as the sun and moon, or the moon and a star, whose distance should, for this purpose, exceed 90 degrees. Move the index, so as to bring the limbs of the sun and moon, if they are made use of exactly, in contact with that wire which is nearest to the plane of the sextant, fix the index there; then, by altering a little the position of your instrument, make the images appear on the wire furthest from the sextant. If the nearest limbs be now precisely in contact as they were before, then the axis of the telescope is in it's right situation. But if the limbs of the two objects appear to separate at the wire that is furthest from the plane of the instrument, it shews that the object end of the telescope inclines towards the plane of the instrument, and must be rectified by tightening the screw nearest the sextant, having previously unturned the screw furthest from it. If the images overlap each other at the wire furthest from the sextant, the highest screw must be turned towards the right, and the lowest screw towards the left: by repeating this operation a few times, the contact will be precisely the same at both wires, and consequently the axis of the telescope will be parallel to the plane of the instrument.

To take the Altitude of the Moon at Sea.

The enlightened edge of the moon, or that edge which is round and well defined, must be brought in contact with the horizon, whether it be the upper or under edge; in other respects the same method is to be used in taking the altitude of the moon as was directed for the sun.

Between new and full moons the enlightened limb is turned towards the weſt: and during the time from the full to the new moon, the enlightened limb is turned towards the eaſt.

If that teleſcope which ſhews objects inverted be uſed, then the upper edge or limb of the moon will appear the lower, the left ſide will appear the right, and the contrary.

The wires of the teleſcope ſhould be turned parallel to the plane of the inſtrument, as by keeping them in a perpendicular direction, they will ſerve at night as a guide for holding the ſextant in a vertical poſition, which cannot otherwiſe at that time be readily aſcertained.

The moon is generally bright enough to be ſeen by reflection from the unſilvered part of the glaſſes; if not, the teleſcope muſt be removed nearer to the plane of the inſtrument.

The obſerved altitude of the moon requires four corrections, in order to obtain the true altitude of her center above the horizon.

Correction 1. For the ſemi-diameter. This is to be found in the nautical almanack, page 7, of every month for every noon and midnight at Greenwich. If the lower limb was obſerved, add the ſemi-diameter thus found. If the upper limb was obſerved, it muſt be ſubtracted.

Correction 2. For the dip of the horizon to be ſubtracted.

Correction 3. For refraction. This is to be ſubtracted.

Correction 4. The moon's parallax in altitude. This is to be added in the observed altitude. It is to be found in the requisite tables to the nautical almanack.

TO DETERMINE THE LONGITUDE AT SEA, BY TAKING THE ANGULAR DISTANCE BETWEEN THE MOON AND ANY CELESTIAL OBJECT.

The latitude is obtained at sea without difficulty, and with as much accuracy as is requisite for nautical purposes; but the motion of the earth on it's axis prevents our ascertaining the longitude with the same facility: and hence it is that most methods of determining the longitude by celestial observation, consist in discovering the difference of apparent time between the two places under consideration.

The angular motion of the moon being much greater than that of any other celestial body, the observation of it's place is much better adapted to discover small differences of time, than similar observations made with any other instrument. The only practical method of observing it's place at sea, is that of measuring the angular distance between it and the sun and a fixed star.

GENERAL DIRECTIONS.

The most obscure, or rather, the least luminous of the two objects must be viewed directly, and the other must be brought by reflection in apparent contact with it.

The well-defined image of the moon must be always made use of for the contact, even though it should be

neceſſary for that purpoſe, to make the reflected image paſs beyond the other.

In the night-time it is neceſſary to turn down one or more of the green ſcreens, to take off the glare of the moon, which would otherwiſe prevent the ſtar from being ſeen.

TO FIND THE DISTANCE BETWEEN THE MOON AND THE SUN.

The central diſtances of the ſun and moon every three hours of time, at Greenwich, on ſuch days as this method is practicable, are ſet down in the nautical almanack. From theſe diſtances you are to compute roughly the diſtance between their neareſt limbs at the time of obſervation.

Mr. Ludlam ſays, the moon ſhould be viewed directly through the unſilvered part of the horizon glaſs, but the ſun by reflection, and if it be very bright, from the unſilvered part of the glaſs.

If the ſun be to the left hand of the moon, the ſextant muſt be held with it's face downwards; but with the face upwards, if the ſun be to the right hand of the moon.

Set the index to the diſtance of the neareſt limbs of the ſun and moon, computed roughly as above; and placing the face of the ſextant agreeable to the foregoing rules, direct the teleſcope to the moon, putting the ſextant into ſuch a poſition, that if you look edge-ways againſt it, it may ſeem to form a line paſſing through the ſun and moon, a circumſtance that can be only attained by practice, the parent of aptneſs; then give the

ſextant

sextant a sweep or swing round a line parallel to the axis of the telescope, and the reflected image of the sun will pass by the moon to and fro, so near, that you cannot fail of seeing it.

The nearest edges, or limbs, may now be brought into exact contact, by moving the index, and then using the adjusting screw; observing, first, that on giving the sextant a motion round the axis of the telescope, the images of the sun and moon only touch at their external edges, and that the body of the sun must not pass over, or be upon the body of the moon. And secondly, that the edge of the sun touch the round or enlightened edge of the moon. Then will the index point out the observed or apparent distance of the nearest edges of the sun and moon.

But the observed distance requires several corrections, before the true distance of the centers of the objects, as seen from the center of the earth, can be found.

Correction 1. Is the sum of their semi-diameters, which is to be added, to give the apparent distance of the centers of the sun and moon.

The semi-diameter of the sun for every sixth day, and of the moon for every noon and midnight, at Greenwich, are to be found in the nautical ephemeris: from these their semi-diameters are to be computed at the time of observation, by the rules to be found in the same work.

Correction 2. Is to free the apparent distance of the effect of refraction and parallax, which will then be the true distance of the centers of the sun and moon, as seen from the earth.

For

For this purpofe, two fets of tables, with directions how to ufe them, are to be found among the requifite tables of the nautical almanack: or by a fet of tables, publifhed for that purpofe by the Board of Longitude.

TO TAKE THE DISTANCE BETWEEN THE MOON AND SUCH STARS AS ARE SELECTED IN THE NAUTICAL ALMANACK, FOR THE PURPOSE OF FINDING THE LONGITUDE AT SEA.

The diftance of thefe ftars from the moon's center for every three hours, at Greenwich, is given in the nautical almanack, from whence their diftance from the enlightened edge may be roughly computed as before.

The ftar muft be viewed directly; the moon is generally bright enough to be feen by reflection from the unfilvered part of the glafs; the proper fhade to take off the glare of the moon is foon found. When the ftar is to the left hand of the moon, the fextant muft be held with it's face upwards; but if the ftar be to the right hand of the moon, with it's face downwards.

Set the index to the diftance roughly computed, and placing the face of the octant by the foregoing rules, direct the telefcope to the ftar. Then place the fextant fo that if feen edge-ways it may feem to form a line paffing through the moon and ftar, and give it a fweep round a line parallel to the axis of the telefcope, and the reflected image of the moon will pafs fo near by the ftar, that you will fee it in the field of the telefcope: a proof that the fight is directed to the right ftar.

The

The enlightened edge of the moon, whether east or west, must then be brought into contact with the star, by moving the index. To know whether the contact is perfect, let the quadrant gently vibrate in a line parallel to the axis of vision, for the star should just graze the edge, without entering at all within the body of the moon; when this is the case, the index will shew the apparent distance of the moon from the star, which, when corrected, gives the true one,

Correction 1. For the semi-diameter of the moon. This may be found in the nautical almanack for every noon and midnight, at Greenwich; and from thence computed, by the rules there given, for the time of observation. If the observed or enlightened limb be nearest the star, the semi-diameter thus found is to be added; if the enlightened edge be the furthest from the star, then the semi-diameter is to be subtracted.

Correction 2. Is for refraction and parallax, to be found from the tables as directed before for the sun and moon.

These corrections being properly made, you have the true distance of the moon's center from the star, as seen from the center of the earth. From this distance, and the time of observation, the longitude may be found.

The star to be observed is always one of the brightest, and lies in a line nearly perpendicular to the horns of the moon, or her longer axis; but if you have any doubt whether the sight be directed to the proper star, set the index to the supposed distance as before, hold the sextant as near as you can judge, so that it's plane, seen edgeways, may coincide with the line of the moon's shorter

axis, and moving it in that plane, ſeek the reflected image of the moon through the teleſcope. Having found the reflected image of the moon, turn the ſextant round the incident ray, that is, a line paſſing from the moon to the inſtrument, and you will perceive through the teleſcope all thoſe ſtars which have the diſtance ſhewn by the index; but the ſtar to be obſerved lies in a line nearly perpendicular to the horns of the moon, there will, therefore, be no danger of miſtaking it.

AN IMPORTANT REMARK.

The following very important obſervation of Mr. Blair's did not occur ſoon enough to be inſerted in it's proper place, and yet was of too much conſequence to be altogether neglected. Beſides the errors already mentioned, to which the Hadley's quadrant, &c. is liable, there is another, which ſeems inſeparable from the conſtruction and materials of the inſtrument. It ariſes from the bending and elaſticity of the index, and the reſiſtance it meets with in turning round it's center.

To obviate this error, let the obſerver be careful always to finiſh his obſervations, by moving the index in the ſame direction which was uſed in ſetting it to 0 for adjuſting, or in finding the index error.

The direction of the motion is indeed indifferent; but as the common practice in obſerving is to finiſh the obſervations by a motion of the index in that direction which increaſes the angle, that is, in the fore obſervation from 0 towards 90, it would be well if the obſerver would adopt it as a general rule, to finiſh the motion of the index, by puſhing it from him, or turning the ſcrew in that direction which carries it farther from him. By finiſhing the motion of the index, we mean that the laſt motion of the index ſhould be for ſome minutes of a degree at leaſt in the required direction.

ASTRONOMICAL

ASTRONOMICAL OBSERVATIONS AT LAND.

THE only neceſſary addition to the ſextant, in order to employ it with ſucceſs in aſtronomical obſervations at land, is an artificial horizon. The portability of the ſextant, it's cheapneſs, compared with other aſtronomical inſtruments, the eaſe with which it is uſed, and the accuracy of the obſervations that may be taken by it, are ſtrong recommendations in it's favour.

The artificial horizon generally uſed, is a ſmall box, or trough, to hold quickſilver, with a parallel plane of glaſs to float on the quickſilver; the glaſs prevents the vacillation of the ſurface of the quickſilver, which would otherwiſe impede the obſervation. To ſcreen the ſurface further from the action of the wind, two planes of parallel glaſs, ſet in a proper frame, in form of the ſlant-roof of a houſe, make a part of the apparatus. The box now in uſe is a contrivance of Mr. Wright's. The quickſilver may be poured in through a hole in the ſide, ſo as to raiſe of itſelf the glaſs plane, which is ground ſo as to fill nearly the circular ſpace within which it floats.

The angle, obſerved by means of the artificial horizon, is always double the altitude of the ſtar, &c. above the horizon; conſequently, you cannot take an altitude of more than 45° with an octant, or of 60 by the ſextant.

Every thing being ready, and the inſtrument properly adjuſted, move backward, till you ſee the reflected image of the ſun in the water. If this image be bright, turn

one or more of the dark glaſſes behind the horizon glaſs.

Hold now the ſextant in a vertical plane, and direct the ſight to the ſun's image in the artificial horizon. Then move the index till you ſee the other image reflected from the mirrors come down to the ſun's image ſeen in the horizon, ſo as to touch, but not paſs it: then bring the edges in contact in the middle between the wires of the teleſcope, as before directed, and the diviſions on the arch will ſhew the double altitude.

Correct the double altitude for the index error, before you halve it. Then to this half altitude add the ſun's ſemi-diameter, and ſubtract the correction for refraction, and you will have the true altitude of the ſun's center above the real horizon.

The altitude of a ſtar muſt be taken in the ſame manner as that of the ſun: the double altitude muſt be corrected for the index error, if any, then halved, and this half corrected for refraction, gives the true altitude above the real horizon.

TO OBSERVE CORRESPONDING ALTITUDES OF THE SUN.

The baſis of all aſtronomical obſervation is the determination of the exact time of any appearance in the heavens. By correſponding altitudes this time may be determined, without the apparatus of a fixed obſervatory; they are alſo uſeful in finding a meridian line, and may be eaſily and accurately made by a ſextant.

For

For theſe obſervations, it is neceſſary to be provided with a clock. Theſe altitudes ſhould be obſerved (in our latitude) at leaſt two hours diſtant from noon. The beſt time is when the ſun is on or near the prime vertical, that is, the eaſt or weſt points of the compaſs.

About theſe times in the forenoon, take ſeveral double altitudes of the ſun, write down the degrees and minutes ſhewn on the arch, and alſo the exact time ſhewn by the clock at each obſervation, and let the different obſervations made in the forenoon be written one below the other in the order they are made.

In the afternoon ſet the index to the ſame degree and minute as the laſt morning obſervation; note very exactly the time ſhewn by the clock when the ſun is come down to the ſame altitude, and write down the times on the right hand of the laſt morning obſervation; proceed in the ſame manner to find the time by the clock, of all the altitudes correſponding to thoſe taken in the morning, and write down each oppoſite to that morning one to which it correſponds.

Take now the firſt pair of correſponding altitudes, add them together, and to half their ſum add ſix hours: this being corrected for the change of the ſun's declination between the morning and evening obſervations, you will have the time of ſolar noon derived from this pair of obſervations. Do the ſame for each pair, and take the mean of the times thus found (from each pair), and you will have the exact time ſhewn by the clock at ſolar noon.

The time, by the clock, of the ſolar or apparent noon being thus obtained, the time of the mean noon may be had, by applying the proper equation of time.

OF HADLEY'S SEXTANT, AS USED IN SURVEYING,

No inſtrument can be ſo conveniently uſed for taking angles in maritime ſurveying, as Hadley's ſextant. It is uſed with equal facility at the maſt head, as upon deck, by which it's ſphere of obſervation is much extended: for ſuppoſing many iſlands to be viſible from the maſt head, and only one from deck, no uſeful obſervation can be made by any other inſtrument. But by this, angles may be taken at the maſt head from the one viſible object with great exactneſs; and further, taking angles from heights, as hills, or a ſhip maſt's head, is almoſt the only way of exactly deſcribing the figure and extent of ſhoals.

It has been objected to the uſe of Hadley's ſextant for ſurveying, that it does not meaſure the horizontal angles, by which alone a plan can be laid down. This obſervation, however true in theory, may be reduced in practice by a little caution.

If an angle be meaſured between an object on an elevation, and another near to it in a hollow, the difference between the baſe, which is the horizontal angle, and the hypothenuſe, which is the angle obſerved, may be very great; but if theſe objects are meaſured, not from each other, but from ſome very diſtant object, the difference between the angles of each from the very diſtant object, will be very near the ſame as the horizontal angle.

This

This may be ſtill further corrected, by meaſuring the angle not between an object on a plane and an object on an elevation, but between the object on a plane and ſome object in the ſame direction, as the elevated object of which the eye is ſufficiently able to judge.

HOW TO OBSERVE THE HORIZONTAL ANGLE, OR ANGULAR DISTANCE, BETWEEN TWO OBJECTS.

Firſt adjuſt the ſextant, and if the objects are not ſmall, pitch on a ſharp top, or corner, or ſome ſmall diſtinct part in each to obſerve; then having ſet the index to 0 deg. hold the ſextant horizontally, as above directed, and as nearly in a plane paſſing through the two objects as you can; direct the ſight through the tube to the left hand object, till it is ſeen directly through the tranſparent part of the horizon glaſs: keeping that object ſtill in ſight there, move the index till the other object is ſeen by reflection in the ſilvered part of the horizon glaſs; then bring both objects together by the index, and by the inclination of the plane of the ſextant when neceſſary, till they unite as one, or appear to join in one vertical line, in the middle of the line which divides the tranſparent and reflecting parts of the horizon glaſs: the two objects thus coinciding, or one appearing directly below the other, the index then ſhews on the limb the angle which the two objects ſubtend at the naked eye. This angle is always double the inclination of the planes of the two reflecting glaſſes to one another; and therefore every degree and minute the index is actually moved from 0, to bring the two objects together, the angle ſubtended by them at the eye will be twice that number of degrees and

 minutes;

minutes; and is accordingly numbered ſo on the arch of the ſextant; which is really an arc of 60 degrees only, but graduated into 120 deg. As this has been demonſtrated in ſeveral books and pamphlets, it is needleſs to inſiſt on it here.

The angle found in this manner between two objects that are near the obſerver, is not preciſe; and may be reckoned exact only when the objects are above half a mile off. For, to get the angle truly exact, the objects ſhould be viewed from the center of the index glaſs, and not where the ſight vane is placed; therefore, except the objects are ſo remote that the diſtance between the index glaſs and ſight vane vaniſhes, or is as nothing compared to it, the angle will not be quite exact. This inaccuracy in the angle between near objects is called the parallax of the inſtrument, and is the angle which the diſtance between the index glaſs and ſight vane ſubtends at any near object. It is ſo ſmall, that a ſurveyor will ſeldom have occaſion to regard it; but if it ſhall happen that great accuracy is required, let him chuſe a diſtant object exactly in a line with each of the near ones, and take the angles between them, and that will be the true angle between the near objects. Or, obſerve the angle between near objects, when the ſextant has been firſt properly adjuſted by a diſtant object; then adjuſt it by the left-hand object, which will bring the index on the arch of exceſs beyond 0 degrees: add that exceſs to the angle found between the objects, and the ſum will be the true angle between them. If one of the objects is near, and the other diſtant, and no remote object to be found in a line with the near one, adjuſt the ſextant to the near object, and then take the

the angle between them, and the error of parallax will be removed.

TO EXAMINE THE GLASSES OF A SEXTANT, OR QUADRANT.

1. To find whether the two ſurfaces of any one of the reflecting glaſſes be parallel, apply your eye at one end of it, and obſerve the image of ſome object reflected very obliquely from it; if that image appears ſingle, and well defined about the edges, it is a proof that the ſurfaces are parallel: on the contrary, if the edge of the reflected images appear miſted, as if it threw a ſhadow from it, or ſeparated like two edges, it is a proof that the two ſurfaces of the glaſs are inclined to each other: if the image in the ſpeculum, particularly if that image be the ſun, be viewed through a ſmall teleſcope, the examination will be more perfect.

2. To find whether the ſurface of a reflecting glaſs be plane. Chuſe two diſtant objects, nearly on a level with each other; hold the inſtrument in an horizontal poſition, view the left hand object directly through the tranſparent part of the horizon glaſs, and move the index till the reflected image of the other is ſeen below it in the ſilvered part; make the two images unite juſt at the line of ſeparation, then turn the inſtrument round ſlowly on it's own plane, ſo as to make the united images move along the line of ſeparation of the horizon glaſs. If the images continue united without receding from each other, or varying their reſpective poſition, the reflecting ſurface is a good plane.

3. To

3. To find if the two ſurfaces of a red or darkening glaſs are parallel and perfectly plane. This muſt be done by means of the ſun when it is near the meridian, in the following manner: hold the ſextant vertically, and direct the ſight to ſome object in the horizon, or between you and the ſky, under the ſun; turn down the red glaſs, and move the index till the reflected image of the ſun is in contact with the object ſeen directly: fix then the index, and turn the red glaſs round in it's ſquare frame; view the ſun's image and object immediately, and if the ſun's image is neither raiſed nor depreſſed, but continues in contact with the object below, as before, then the ſurfaces of the darkening glaſs are true

TABLE I.

A TABLE of the DEPRESSION or DIP of the HORIZON of the SEA.

Elevation of the Eye above the Sea in Feet.	Depression of the Horizon of the Sea. ′	″
1	0.	57
2	1.	21
3	1.	39
4	1.	55
5	2.	8
6	2.	20
7	2.	31
8	2.	42
9	2.	52
10	3.	1
12	3.	18
14	3.	34
16	3.	49
18	4.	3
20	4.	16
22	4.	28
24	4.	40
26	4.	52
28	5.	3
30	5.	14
35	5.	39
40	6.	2
45	6.	24
50	6.	44
60	7.	23
70	7.	59
80	8.	32
90	9.	8
100	9.	33

TABLE II.

A Table of the Refraction of the Heavenly Bodies in Altitude.

App. Alt.	Refr.	App. Alt.	Refr.	App. Alt.	Refr.	App. Alt.	Refr.	App. Alt.	Refr.
° ′	′ ″	° ′	′ ″	° ′	′ ″	° ′	′ ″	° ′	′ ″
0 0	33 0	4 50	10 11	10 30	5 0	26 0	1 56	59 0	0 34
0 5	32 10	5 0	9 54	10 45	4 53	27	1 51	60	33
0 10	31 22	5 10	9 38	11 0	4 47	28	1 47	61	32
0 15	30 35	5 20	9 23	11 15	4 40	29	1 42	62	30
0 20	29 50	5 30	9 8	11 30	4 34	30	1 38	63	29
0 30	28 22	5 40	8 54	11 45	4 29	31	1 35	64	28
0 32	28 5	5 50	8 41	12 0	4 23	32	1 31	65	26
0 36	27 30	6 0	8 28	12 20	4 16	33	1 28	66	25
0 40	27 0	6 10	8 15	12 40	4 9	34	1 24	67	24
0 50	25 42	6 20	8 3	13 0	4 3	35	1 21	68	23
1 0	24 29	6 30	7 51	13 20	3 57	36	1 18	69	22
1 10	23 20	6 40	7 40	13 40	3 51	37	1 16	70	21
1 20	22 15	6 50	7 30	14 0	3 45	38	1 13	71	19
1 30	21 15	7 0	7 20	14 20	3 40	39	1 10	72	18
1 40	20 18	7 10	7 11	14 40	3 35	40	1 8	73	17
1 50	19 25	7 20	7 2	15 0	3 30	41	1 5	74	16
2 0	18 35	7 30	6 53	15 30	3 24	42	1 3	75	15
2 10	17 48	7 40	6 45	16 0	3 17	43	1 1	76	14
2 20	17 4	7 50	6 37	16 30	3 10	44	59	77	13
2 30	16 24	8 0	6 29	17 0	3 4	45	57	78	12
2 40	15 45	8 10	6 22	17 30	2 59	46	55	79	11
2 50	15 9	8 20	6 15	18 0	2 54	47	53	80	10
3 0	14 36	8 30	6 8	18 30	2 49	48	51	81	9
3 10	14 4	8 40	6 1	19 0	2 44	49	49	82	8
3 20	13 34	8 50	5 55	19 30	2 39	50	48	83	7
3 30	13 6	9 0	5 48	20 0	2 35	51	46	84	6
3 40	12 40	9 10	5 42	20 30	2 31	52	44	85	5
3 50	12 15	9 20	5 36	21 0	2 27	53	43	86	4
4 0	11 51	9 30	5 31	21 30	2 24	54	41	87	3
4 10	11 29	9 40	5 25	22 0	2 20	55	40	88	2
4 20	11 8	9 50	5 20	23 0	2 14	56	38	89	1
4 30	10 48	10 0	5 15	24 0	2 7	57	37	90	0
4 40	10 29	10 15	5 7	25 0	2 2	58	35		

TABLE III.

A TABLE of the SUN's DECLINATION for the First Year after Leap-Year.

Days.	Jan.	Feb.	Marc.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
	South	South	South	North	North	North	North	North	North	South	South	South
	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.
1	22 58	16 54	7 19	4 48	15 16	22 9	23 6	17 54	8 3	3 26	14 40	21 56
2	22 53	16 37	6 56	5 11	15 34	22 17	23 2	17 39	7 43	3 49	14 59	22 5
3	22 46	16 19	6 33	5 34	15 52	22 24	22 57	17 23	7 21	4 12	15 17	22 14
4	22 40	16 1	6 10	5 57	16 9	22 31	22 52	17 7	6 59	4 35	15 36	22 22
5	22 33	15 43	5 47	6 19	16 26	22 38	22 46	16 51	6 37	4 58	15 54	22 29
6	22 26	15 24	5 24	6 42	16 43	22 44	22 40	16 34	6 14	5 22	16 12	22 36
7	22 18	15 6	5 0	7 5	17 0	22 50	22 33	16 18	5 52	5 45	16 30	22 43
8	22 10	14 47	4 37	7 27	17 16	22 55	22 27	16 1	5 29	6 8	16 47	22 49
9	22 01	14 27	4 14	7 49	17 32	23 0	22 19	15 43	5 6	6 30	17 4	22 55
10	21 52	14 8	3 50	8 11	17 47	23 5	22 12	15 26	4 44	6 53	17 21	23 0
11	21 42	13 47	3 27	8 33	18 3	23 9	22 4	15 8	4 21	7 16	17 38	23 5
12	21 33	13 27	3 3	8 55	18 18	23 13	21 56	14 50	3 58	7 38	17 54	23 10
13	21 22	13 7	2 39	9 17	18 33	23 16	21 47	14 31	3 35	8 1	18 10	23 14
14	21 11	12 47	2 16	9 38	18 47	23 19	21 38	14 13	3 12	8 23	18 26	23 17
15	21 0	12 26	1 52	10 0	19 1	23 22	21 28	13 54	2 48	8 46	18 41	23 20
16	20 49	12 5	1 28	10 21	19 15	23 24	21 18	13 35	2 25	9 8	18 56	23 23
17	20 37	11 44	1 5	10 42	19 29	23 25	21 8	13 16	2 2	9 30	19 11	23 25
18	20 25	11 23	0 41	11 3	19 42	23 27	20 58	12 56	1 39	9 52	19 25	23 26
19	20 12	11 2	0 17	11 24	19 55	23 28	20 47	12 37	1 15	10 13	19 39	23 27
20	19 59	10 40	N. 6	11 44	20 7	23 28	20 35	12 17	0 52	10 35	19 52	23 28
21	19 45	10 18	0 30	12 5	20 19	23 28	20 24	11 57	0 29	10 56	20 6	23 28
22	19 31	9 56	0 54	12 25	20 31	23 28	20 12	11 37	0 5	11 18	20 18	23 28
23	19 17	9 34	1 17	12 45	20 42	23 27	20 0	11 16	S. 18	11 39	20 31	23 27
24	19 3	9 12	1 41	13 4	20 54	23 26	19 47	10 56	0 42	12 0	20 43	23 26
25	18 48	8 50	2 5	13 24	21 4	23 24	19 34	10 35	1 5	12 20	20 55	23 24
26	18 33	8 27	2 28	13 43	21 15	23 22	19 21	10 14	1 29	12 41	21 6	23 22
27	18 17	8 5	2 52	14 2	21 25	23 20	19 7	9 53	1 52	13 1	21 17	23 19
28	18 1	7 42	3 15	14 21	21 34	23 17	18 53	9 32	2 15	13 21	21 27	23 16
29	17 45		3 38	14 40	21 44	23 14	18 39	9 10	2 39	13 41	21 37	23 13
30	17 28		4 2	14 58	21 53	23 10	18 24	8 49	3 2	14 1	21 47	23 9
31	17 12		4 25		22 1		18 10	8 27		14 20		23 4

A Table of the Sun's Declination for the Second Year after Leap-Year.

Days.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
	South	South	South	North	North	North	North	North	North	South	South	South
	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.
1	22 59	16 58	7 25	4 42	15 12	22 7	23 7	17 58	8 10	3 20	14 35	21 54
2	22 54	16 41	7 2	5 5	15 30	22 15	23 3	17 43	7 49	3 43	14 54	22 3
3	22 48	16 23	6 39	5 28	15 47	22 23	22 58	17 27	7 26	4 7	15 13	22 12
4	22 42	16 5	6 16	5 51	16 5	22 30	22 53	17 11	7 4	4 30	15 32	22 20
5	22 35	15 47	5 53	6 14	16 22	22 36	22 47	16 55	6 42	4 53	15 50	22 27
6	22 27	15 29	5 29	6 37	16 39	22 43	22 41	16 38	6 20	5 16	16 8	22 35
7	22 20	15 10	5 6	6 59	16 56	22 48	22 35	16 23	5 57	5 39	16 26	22 41
8	22 12	14 51	4 43	7 21	17 12	22 54	22 28	16 5	5 34	6 2	16 43	22 48
9	22 3	14 32	4 19	7 44	17 28	22 59	22 21	15 47	5 12	6 25	17 0	22 54
10	21 54	14 12	3 56	8 6	17 44	23 4	22 14	15 30	4 49	6 48	17 17	22 59
11	21 45	13 52	3 32	8 28	17 59	23 8	22 6	15 12	4 26	7 11	17 34	23 4
12	21 35	13 32	3 9	8 50	18 14	23 12	21 58	14 54	4 3	7 33	17 50	23 8
13	21 25	13 12	2 45	9 12	18 29	23 15	21 49	14 36	3 40	7 56	18 6	23 12
14	21 14	12 52	2 21	9 33	18 44	23 18	21 40	14 17	3 17	8 18	18 22	23 16
15	21 3	12 31	1 58	9 55	18 58	23 21	21 31	13 58	2 54	8 40	18 37	23 20
16	20 52	12 10	1 38	10 16	19 12	23 23	21 21	13 40	2 31	9 3	18 52	23 22
17	20 40	11 49	1 10	10 37	19 25	23 25	21 11	13 20	2 7	9 24	19 7	23 24
18	20 28	11 28	0 47	10 58	19 39	23 26	20 0	13 1	1 44	9 47	19 22	23 26
19	20 15	11 7	0 23	11 19	19 52	23 27	20 49	12 41	1 21	10 8	19 36	23 27
20	20 2	10 45	N. 1	11 39	20 4	23 28	20 38	12 22	0 57	10 30	19 49	23 28
21	19 48	10 23	0 24	12 0	20 16	23 28	20 27	12 2	0 34	10 51	20 2	23 28
22	19 35	10 2	0 48	12 20	20 28	23 28	20 15	11 41	0 11	11 13	20 15	23 28
23	19 21	9 40	1 12	12 40	20 40	23 27	20 3	11 21	S. 13	11 34	20 28	23 27
24	19 6	9 17	1 35	13 0	20 51	23 26	19 50	11 1	0 36	11 55	20 40	23 26
25	18 51	8 55	1 59	13 19	21 2	23 25	19 37	10 40	1 0	12 15	20 52	23 25
26	18 36	8 33	2 22	13 39	21 12	23 23	19 24	10 19	1 23	12 36	21 3	23 23
27	18 21	8 10	2 46	13 58	21 22	23 21	19 10	9 58	1 46	12 56	21 14	23 20
28	18 5	7 48	3 9	14 17	21 32	23 18	18 57	9 37	2 10	13 17	21 25	23 17
29	17 49		3 33	14 35	21 41	23 15	18 42	9 15	2 33	13 36	21 35	23 14
30	17 32		3 56	14 54	21 50	23 11	18 28	8 54	2 57	13 56	21 45	23 10
31	17 15		4 19		21 59		18 13	8 32		14 16		23 5

A Table of the Sun's Declination for the Third Year after Leap-Year.

Days.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
	South	South	South	North	North	North	North	North	North	South	South	South
	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.
1	23 0	17 2	7 30	4 36	15 8	22 5	23 8	18 2	8 16	3 14	14 30	21 52
2	22 55	16 45	7 7	5 0	15 26	22 13	23 4	17 46	7 54	3 38	14 50	22 1
3	22 49	16 28	6 44	5 23	15 43	22 21	22 59	17 31	7 32	4 1	15 8	22 10
4	22 43	16 10	6 21	5 46	16 1	22 28	22 54	17 15	7 10	4 24	15 27	22 18
5	22 36	15 51	5 58	6 8	16 18	22 35	22 49	16 59	6 47	4 48	15 45	22 26
6	22 29	15 33	5 35	6 31	16 35	22 41	22 43	16 42	6 25	5 11	16 4	22 33
7	22 22	15 14	5 12	6 54	16 52	22 47	22 37	16 26	6 2	5 34	16 21	22 40
8	22 14	15 55	4 48	7 16	17 8	22 53	22 30	16 9	5 40	5 57	16 39	22 46
9	22 5	14 36	4 25	7 39	17 24	22 58	22 23	15 51	5 17	6 20	16 56	22 52
10	21 56	14 17	4 1	8 1	17 40	23 3	22 16	15 34	4 54	6 42	17 13	22 58
11	21 48	13 57	3 38	8 23	17 55	23 7	22 8	15 16	4 32	7 5	17 30	23 3
12	21 37	13 37	3 14	8 43	18 11	23 11	21 0	14 58	4 9	7 28	17 46	23 7
13	21 27	13 17	2 51	9 7	18 26	23 15	21 51	14 40	3 46	7 50	18 2	23 12
14	21 17	12 57	2 27	9 28	18 40	23 18	21 42	14 22	3 23	8 13	18 18	23 15
15	21 6	12 36	2 3	9 50	18 54	23 20	21 33	14 3	3 0	8 35	18 34	23 19
16	20 54	12 15	1 40	10 11	19 8	23 23	21 23	13 44	2 36	8 57	18 49	23 21
17	20 43	11 54	1 16	10 32	19 22	23 25	21 13	13 25	2 13	9 19	19 4	23 24
18	20 31	11 33	0 52	10 53	19 35	23 26	21 3	13 6	1 50	9 41	19 18	23 25
19	20 18	11 12	0 29	11 14	19 48	23 27	20 52	12 46	1 27	10 3	19 32	23 27
20	20 5	10 50	0 5	11 34	20 1	23 28	20 41	12 26	1 3	10 25	19 46	23 28
21	19 52	10 29	N. 19	11 55	20 13	23 28	20 20	12 7	0 40	10 46	19 59	23 28
22	19 38	10 7	0 42	12 15	20 24	23 28	20 18	11 46	0 16	11 7	20 12	23 28
23	19 24	9 45	1 6	12 35	20 37	23 27	20 6	11 26	S. 7	11 29	20 25	23 28
24	19 10	9 23	1 30	12 55	20 48	23 27	19 53	11 6	0 31	11 50	20 37	23 27
25	18 55	9 1	1 53	13 15	20 59	23 25	19 40	10 45	0 54	12 10	20 49	23 25
26	18 40	8 38	2 17	13 34	21 10	23 23	19 27	10 24	1 17	12 31	21 1	23 23
27	18 24	8 16	2 40	13 53	21 20	23 21	19 14	10 3	1 41	12 51	21 12	23 21
28	18 9	7 53	3 4	14 12	21 30	23 18	19 0	9 42	2 4	13 12	21 22	23 18
29	17 53		3 27	14 31	21 39	23 15	18 46	9 20	2 28	13 32	21 33	23 14
30	17 36		3 50	14 49	21 48	23 12	18 31	8 59	2 51	13 52	21 43	23 11
31	17 19		4 14		21 57		18 17	8 37		14 11		23 6

A Table of the Sun's Declination for Leap-Year.

Days.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
	South	South	South	North	North	North	North	North	North	South	South	South
	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.
1	23 2	17 7	7 14	4 53	15 21	22 1[illegible]	23 5	17 51	8 0	3 31	14 44	21 59
2	22 57	16 50	6 52	5 16	15 38	22 19	23 1	17 35	7 38	3 55	15 3	22 7
3	22 51	16 32	6 28	5 39	15 56	22 26	22 56	17 19	7 16	4 18	15 22	22 16
4	22 45	16 15	6 5	6 2	16 13	22 33	22 50	17 3	6 54	4 41	15 40	22 24
5	22 38	15 57	5 42	6 25	16 30	22 39	22 45	16 47	6 31	5 4	15 59	22 31
6	22 31	15 38	5 18	6 47	16 47	22 45	22 38	16 30	6 9	5 27	16 17	22 38
7	22 24	15 20	4 55	7 10	17 3	22 51	22 32	16 14	5 46	5 50	16 34	22 45
8	22 16	15 1	4 31	7 32	17 20	22 56	22 25	15 56	5 24	6 13	16 52	22 51
9	22 8	14 41	4 8	7 55	17 36	23 1	22 18	15 39	5 1	6 36	17 9	22 56
10	21 59	14 22	3 44	8 17	17 51	23 6	22 10	15 21	4 38	6 59	17 25	23 1
11	21 50	14 2	3 21	8 39	18 6	23 10	22 2	15 3	4 15	7 21	17 42	23 6
12	21 40	13 43	2 57	9 0	18 21	23 14	21 54	14 45	3 52	7 44	17 58	23 11
13	21 30	13 23	2 34	9 22	18 36	23 17	21 45	14 27	3 29	8 6	18 14	23 14
14	21 20	13 2	2 10	9 44	18 51	23 20	21 35	14 8	3 6	8 29	18 29	23 18
15	21 9	12 42	1 46	10 5	19 5	23 22	21 26	13 49	2 43	8 51	18 45	23 21
16	20 58	12 21	1 23	10 26	19 18	23 24	21 16	13 30	2 20	9 13	19 0	23 23
17	20 46	12 0	0 59	10 47	19 32	23 26	21 6	13 11	1 56	9 35	19 14	23 25
18	20 34	11 39	0 35	11 8	19 46	23 27	20 55	12 52	1 33	9 57	19 28	23 27
19	20 21	11 18	0 12	11 29	19 58	23 28	20 44	12 32	1 10	10 19	19 42	23 28
20	20 9	10 56	N. 12	11 49	20 10	23 28	20 33	12 12	0 46	10 40	19 56	23 28
21	19 55	10 35	0 34	12 9	20 22	23 28	20 21	11 52	0 23	11 2	20 9	23 28
22	19 42	10 13	0 59	12 30	20 34	23 28	20 9	11 32	S. 0	11 23	20 21	23 28
23	19 28	9 51	1 23	12 49	20 45	23 27	19 57	11 11	0 24	11 44	20 34	23 27
24	19 14	9 29	1 47	13 9	20 56	23 26	19 44	10 51	0 47	12 5	20 46	23 26
25	18 59	9 7	2 10	13 29	21 7	23 24	19 31	10 30	1 11	12 25	20 57	23 24
26	18 44	8 44	2 34	13 48	21 17	23 23	19 17	10 9	1 34	12 46	21 9	23 22
27	18 29	8 32	2 57	14 7	21 27	23 19	19 4	9 48	1 58	13 6	21 19	23 19
28	18 13	7 59	3 21	14 26	21 37	23 16	18 50	9 27	2 21	13 26	21 30	23 15
29	17 57	7 37	3 49	14 44	21 46	23 13	18 35	9 5	2 45	13 46	21 40	23 12
30	17 41		4 7	15 2	21 55	23 9	18 21	8 44	3 8	14 6	21 49	23 8
31	17 24		4 30		22 3		18 6	8 22		14 26		23 3

A

C A T A L O G U E,

O F

Mathematical and Philoſophical Inſtruments, made and ſold by George Adams, No. 60, Fleet-Street.

Optical Inſtruments.

	£.	s.	d.
THE beſt double-jointed ſilver ſpectacles, with glaſſes	1	1	0
The beſt ditto, with Brazil pebbles	1	16	0
Single joint ſilver ſpectacles, with glaſſes	0	15	0
Ditto, with Brazil pebbles	1	10	0
Double joint ſteel ſpectacles, with glaſſes	0	10	6
Another ſort of ditto	0	7	6
Beſt ſingle joint ſpectacles	0	5	0
Ditto, inferior frames	0	3	6
Noſe ſpectacles, mounted in ſilver	0	7	0
Ditto, in tortoiſeſhell and ſilver	0	4	0
Ditto, in horn and ſteel	0	1	0
Spectacles for couched eyes			
Spectacles with ſhades			
Concave glaſſes in horn boxes, for ſhort-ſighted eyes			
Reading glaſſes, from 2s. 6d. to	2	2	0
Opera glaſſes, from 10s. 6d. to	2	2	0
Teleſcopes of various lengths, ſizes, and prices			
Teleſcopes to uſe at ſea by night	1	11	6
Acromatic proſpects, from 15s. to	2	12	6
Acromatic teleſcopes, with braſs drawers, which may be drawn out at once, and that ſhut up, conveniently for the pocket, from 1l. 11s. 6d. to	13	13	0

The Price of Adams's Globes.

	£.	s.	d.
28 Inches diameter, mounted in mahogany frames	52	10	0
28 Ditto, frames carved and ornamented			
18 Ditto, mounted in the common manner	6	6	0
18 Ditto, mounted in the common manner in mahogany frames	8	8	0
18 Ditto, mounted in the beſt manner, in ſtained frames	10	10	0
18 Ditto, mounted in the beſt manner, in mahogany frames	12	12	0
18 Ditto, mounted in the beſt manner, in carved frames	16	16	0
16 Ditto, mounted in the common manner	6	6	0
12 Ditto, mounted in the common manner	3	3	0
12 Ditto, mounted in the common manner, in mahogany frames	[illegible]	[illegible]	[illegible]

	£.	s.	d.
12 Ditto, mounted in the beſt manner, in mahogany frames ———	7	7	0
9 Ditto, mounted in the common manner —	2	2	0
9 Ditto, mounted in the beſt manner —	4	4	0
6 Ditto, mounted in the beſt manner ——	3	3	0
3 Ditto, mounted in the beſt manner ——	1	11	6
3 Ditto, for the pocket ———	0	10	6

Inſtruments for Navigation.

	£.	s.	d.
Caſes of inſtruments and teleſcopes of different kinds, ſizes, and prices			
Night teleſcopes, from 1l. 11s. 6d. to ———	2	2	0
An opera glaſs for the ſame purpoſe —	1	11	6
A teleſcope with an eye-glaſs micrometer, for determining the diſtance of a ſhip at ſea			
Hadley's quadrants in mahogany frames —	2	2	0
Ditto, in black ebony frames ———	3	3	0
Ditto, on the beſt conſtruction ———	4	14	6
Hadley's ſextant in wood ———	6	16	6
Ditto in braſs, on the moſt improved plan, from 11l 11s. to —— ——	15	15	0
Knight's ſteering compaſs, with improvements	2	12	6
Knight's azimuth ditto ———	5	15	6
Ditto, on friction wheels ———	10	10	0
Marine barometers; by theſe ſtorms have been foretold at ſea ſome hours before they happened			
Circular inſtruments, to anſwer the purpoſe of the ſextant —— ——	14	14	0
Dipping needles, from 12l. 12s. to —	31	10	0
An inſtrument to uſe inſtead of the minute glaſs, but much more accurate ———	2	2	0

Meteorological Inſtruments.

	£.	s.	d.
A plain portable barometer ——	2	2	0
Ditto, with a thermometer ———	3	3	0
A plain barometer, covered frame and glaſs door	2	12	6
Ditto, with a thermometer ——	3	13	6
A barometer with a long cylindric thermometer	4	4	0
A ditto with ditto, and De Luc's hygrometer	7	7	0
A barometer and thermometer, with a guage, the indexes moving by rack-work ——	5	15	6
A barometer for meaſuring the altitude of mountains, &c. — ——	9	9	0
Marine barometers			
Diagonal, wheel, and ſtatical barometers			
Fahrenheit's thermometers, from 1l. 1s. to —	2	12	6
Ditto, for botanic purpoſes ———	0	18	0
Ditto, for the brewery	1	1	0